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An overview of renewable energy in Spain. The small hydro-power case

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Abstract

Development of hydroelectric energy, a renewable source of power, is guaranteed and maintained by the Plan of Promotion of the Renewable Energies 1999–2010 (PLAFER). This is arrived at by means of a definition and establishment of a series of power objectives in which an increase in the hydroelectric sector is anticipated. This study corresponds to a revision of the present situation of the mini-hydraulic energy, it is expected of evolution, and development in Spain.

Keywords: Renewable energy; Small hydro-power; Electricity market

Contents

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1. Introduction

Power Sector is a basic constituent for the development of worldwide economy; its evolution is based on making quality compatible with service, as it is the only means to lay the foundation of a stable sharp and economic growth.

This consideration has been described by the Ministry of Economy as [1] "The Power sector constitutes an essential part of the economic activity of a country being a dynamic element of the same, as well as, it supposes an undeniable strategic value to the rest of the sectors of the economy. For that reason, the power provision in optimal conditions of security, quality and price is a not to be waived objective in the definition of the power policy of a country".

2. European overview of the renewable energies

Environmental impact of electrical generation by conventional sources of energy does not limit emission to the atmosphere, even though the reduction or containment of these emissions constitutes priority for all the signatory countries of the Kioto Protocol [2].

Framed against the European background, the environmental problem associated to the power sector has its origin in the Programs of Action especially the one in force at the moment, VI Program of Action of the European Community (2001) 'The environment 2010: the future in our hands.'[1]

This beginning for integration of renewable energies is made official in the publication of Green Book [3] of the European Commission. It analyzed, the answers published in the White Book [4] where not only *environment* is defined, but also the *security of provision and the competitiveness* on which the European power policy is based are described [5].

Directive 96/92/CE of the European Parliament and the Council, on the domestic market of the electricity, enunciates the objectives: to assure the provision of energy and its quality at lower cost, to establish and maintain competitiveness of the European

[1] COM n. 31 (2001). Not published in the official newspaper. Communication of the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, of 24th January, 2001, on the Sixth Program of Action of the European Community in the matter of the Environment 'The Environment 2010: the future in our hands'.

economic operators who depend on the energy and protect the environment [6]. In addition, it is also stressed that preference should be given by suitable regulation to renewable electric energy.

Directive 2001/77/CE, approved in September 2001, states the objectives of electrical generation produced by renewable power plants.

3. Spanish overview

As a response to the new conditions of the sector, the Spanish power policy promises integration of the environmental aspects of the energy, with the environmental protection in the new Laws of the electrical sector [7] by the creation of an organization-the National Council of the Climate [8]—to analyze and define the Spanish strategy before becoming a signatory of the Kyoto Protocol. With the approval of the Plan of Promotion of the Renewable Energies (PLAFER), Spain is taking measures to ensure that by 2010, 12% of the total energy produced would be renewable energy.

As seen in the Plan of Promotion of the Renewable Energies[2] "Spain has acquired the commitment of not increasing the gas discharges conservatory over 15% in 2010, with respect to the total emissions of 1990".

In July 2000, a study, which calculated the environmental impacts of eight systems of electricity generation [9], for which ecopoints of negative impact are given to each one of them was performed. This unit measures the environmental impact by each tera joule of produced electricity (Fig. 1).

3.1. Instruments of the power policy in Spain

With the objective of boosting, the use of the renewable power plants and to obtain greater power efficiency, the following programs and institutions have been developed at the national level.

The Power, Environmental Research Center and Technological (CIEMAT)[3] has the following aims to contribute solutions to improve the use of resources and systems for energy generation, to develop alternative power sources, and to solve the problems of the Spanish companies in the areas of the energy and its repercussion to the environment.

The Institute for the Diversification and Saving of the Energy (IDAE) has as its basic function to promote power efficiency and rational use of energy in Spain, as well as the diversification of the power plants and the promotion of the renewable energies.

[2] The programs of promotion of the renewable energies constitute a necessary, although not enough, performance to reach the objectives established in the Kioto protocol (p. 14).

[3] A Public organisation of investigation and assigned technological development, assigned by the Ministry of Economy, through the Secretariat of State of Energy, Industrial Development and of Small and Medium Company. Initiated according to Real Decree 802/1986 of 11/04/86, which delineates the statute of the Institute for the Diversification and Saving of the Energy. BOE 100/1986 of the 26/04/1986. Modified later with Real Decree 252/1997 of 21/02/97 of 11 April which explains the statute of the Institute for the Diversification and Saving of the Energy. BOE 54/1997 of the 04/03/1997.

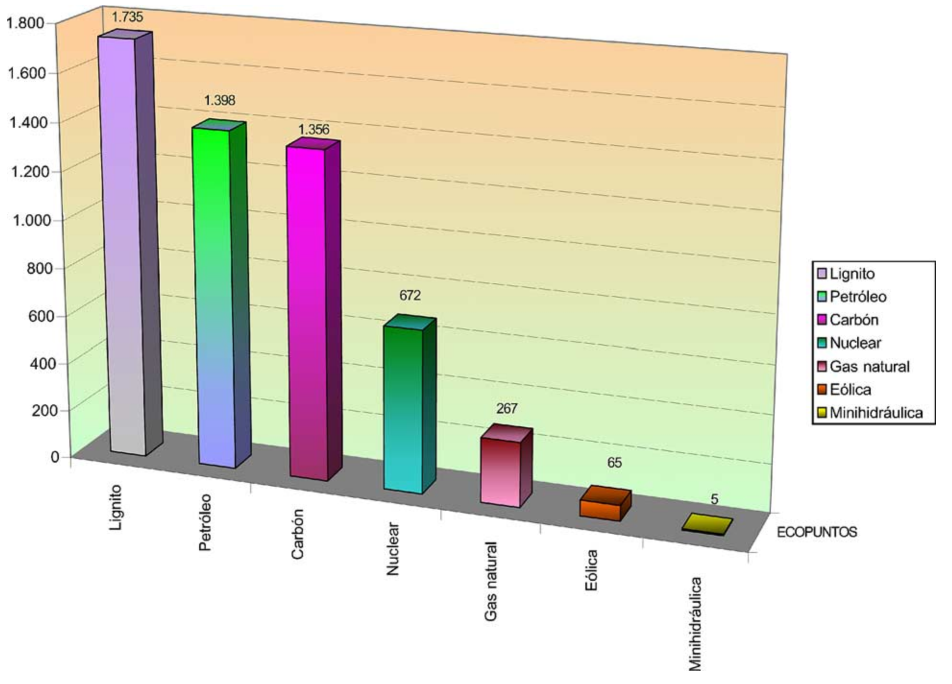


Fig. 1. Total ecopoints for each technology. *Source*: own elaboration from AUMA data (2000).

The APPA group has more than 200 small and medium companies that generate electricity starting off of renewable power plants. It was created in 1987, being the only association that is represented in the Consultative Council of Electricity of the National Commission of Energy (CNE). This body regulates power systems, and comprises the Committee of Agents of the Spanish market of electricity and different organisations.

In 1990, the Plan of Saving and Power Efficiency (PAEE), which is a part of the National Power Plan, received a commitment from the Ministry of Industry and Energy to boost renewable energies within the Spanish power scenario.

In 1997, under the Program of Saving and Power Efficiency, PAEE approved the new Law of the Electrical Sector and the Special Regime of the Renewable Energies, *Law 54/1997 of the Electrical Sector*, for concession to renewable energy sectors. This law, which was enforced on January 1, 1998, constitutes the basic norm on which the new liberalized and competitive electrical system is based. The aim of this law was not to regularize the electrical sector, but to guarantee electricity quality, at the least expense possible, without damaging the environment [10].

The law distinguishes two groups of generation:

- Ordinary regime for conventional power stations.
- Special regime for installation of high power efficiency (cogeneration), with renewable energies and those that eliminate any environmental harm.

On 23rd December 1998, *the Real Decree 2818/1998* was approved for production of electrical energy by supply facilities or renewable power plants, remainders and cogeneration, which the Special Regime of the Electrical Sector later develops. This Real Decree develops Law 54/1997 in which it talks about the special regime; it not only anticipates the update of premiums based on a series of variables properly weighed, update that has been made for year 2002 by third consecutive year, but also the revision of the premiums every 4 years taking care of the price change of the electrical energy in the market. It is to be emphasized that in this R.D., the definition of the facilities of producers in special regime is laid down for the first time, distinguishing several groups (art. 2) which includes the 'b.4 Central hydro-electric whose power is not superior to 10 MW'.

Following the directives of the White Book of the Renewable Energies of the European Commission, the Spanish state finalized a scheme of the Ministry of Industry and Energy, through the IDAE, a Plan of Promotion of the Renewable Energies (1999–2010) PLAFER and of a Plan of Action (1999–2005) on renewable energy. In the PLAFER, points and considerations necessary to achieve growth in different areas of renewable energies and production of at least 12% of renewable energy in 2010 are delineated.

3.2. Electrical market

Control and administration of the Spanish electrical system falls under Law of the Electrical Sector, Law 54/1997, and the Real Decree 2019/1997, of 26th December. The same law also distinguishes between the economic management and the technical management of the market and responsibilities are entrusted to the Operator of Market (OMEL) and to the Operator of the System, Mains (REE), respectively.

The operation of the REE in the Spanish electrical system is based on controlling and operating the system in real time and guaranteeing error-free coordination between the generation from the electrical power stations and the transport of energy, ensuring the continuity and security of the electrical provision always. It also offers daily updates of the production market, in the form of a graphical summary, along with details of the programmed energy and the price of the energy for each hour of the previous day. The OMEL is the person in charge of the economic management: it manages the system of supplies, of purchase and sales of energy that the different agents carry out in the production market and makes the resulting final liquidation.

The liberalization of the electricity market in 2003 (as is reflected in Table 1) was made based on Article 5 of Directive 2001/77/CE which allows the consumer to choose the type of electricity that one wishes to consume.

From 1st January 2003, consumers were able to acquire energy from a better supplier, unlike the earlier scenario where they had to choose a supplier based on geographical location.

3.3. Production in special regimen

It is in the old Real Decree 2366/1994 of 9th December, where the first definition of special regime scores like facilities of production of electrical energy by hydraulic power

Table 1
Calendar of access to the condition of qualified client

Date	Requirement
1 January, 1998	Annual consumption > 15 GW h
1 January, 1999	Annual consumption = 15 GW h
1 April, 1999	Annual consumption = 3 GW h
1 July, 1999	Annual consumption = 2 GW h
1 October, 1999	Annual consumption = 1 GW h
1 July, 2000	Provision to tension > 1000 V
1 January, 2003	All the consumers

Source: own elaboration from data of Spanish consumption.

stations, of co-generation and others supplied by resources or renewable power plants, can adhere, associated a procedure of particular invoicing.

Nevertheless, this decree has been replaced by the Real Decree 2818/1998, of 23rd December in that the guidelines to tariff repayment for this sector are laid down.

In the repayment of the renewable energies, and for the case of the mini-hydraulics, two systems of tariff exist. These are:

– variable tariff: price of market + premium + complement by reactive.
– fixed tariff: for renewable, established in different Real Decrees with annual regularity.

In Table 2, the values of the premium for the case of the variable tariff for years 2002 and 2003 are exposed, and Table 3 reflects the fixed prices for the case of fixed tariff. When comparing both tables, it is deduced that for a reduction of 2% of the premium in the case of the variable tariff, the repayment for the case of the fixed price has been increased by 1.7%.

Table 4 shows a comparison of both repaying systems from 1999 to 2003. As can be seen in the great majority of the cases, generators with hydraulic energy view the variable tariff as being more profitable.

Table 2
Electrical tariffs for the generation with renewable energy type b.4

	1999	2000	2001	2002	2003
Fixed tariff	67,313	63647	63,647	63,827	64,909
Premium	3576	2987	2987	30,051	29,464
Considered pool	3522	3842	3817	4422	3901
Variable tariff	70,980[a]	68,290[b]	68,040[c]	74,271[d]	68,474[e]

Source: own elaboration from data of Spanish consumption and mentioned Real Decrees.
[a] Real Decree 2821/1998, of 23rd December, where electrical tariff for 1999 is arrived at.
[b] Real Decree 2066/1999, of 30th December, the electrical tariff for 2000. (Effective until 25th June, 2000).
[c] Real Decree 3490/2000, of 29th December, the electrical tariff for 2001. (Effective until 1st January, 2001).
[d] Real Decree 1483/2001, of 27th December, the electrical tariff for 2002. (Effective until the 1st January, 2003).
[e] Real Decree 1436/2002, of 27th December, the electrical tariff for 2003 settles down.

Table 3
Consumption of primary energy

Ktep	2001		2000		1999		1998	
Coal	19,457	15.2%	21,635	17.3%	20,519	17.2%	17,889	15.7%
Petroleum	66,719	52.2%	64,663	51.7%	63,041	52.8%	61,670	54.0%
Natural gas	16,405	12.8%	15,223	12.2%	13,535	11.3%	11,816	10.3%
Hydroelectric	3526	2.8%	2534	2.0%	2246	1.9%	3103	2.7%
Renewable	4776	3.7%	4513	3.6%	4221	3.5%	4060	3.6%
Nuclear	16,602	13.0%	16,211	13.0%	15,337	12.8%	15,376	13.5%
Electr. balance	298	0.2%	382	0.3%	492	0.4%	293	0.3%
Total	127,783	100.0%	125,161	100.0%	119,391	100.0%	114,207	100.0%

Source: own elaboration from data of IDAE/Ministry of Economy-Main directory of Power Policy and Mines, 2001.

Table 4
Values of National Generation, values are percentage of Renewable and mini hydraulic

	1998	2010
Total national gross generation (GW h)	196.139	276.692
% of Renewable	20.20	27.70
% of Minihidraulic	2.90	2.50

Source: own elaboration from data of the PLAFER (1999).

For the calculation of the invoicing, the following is applied:

$$F_b = E_v \times (P_{mv} + \mathrm{Pr}) + E_p \times (P_{mp} + \mathrm{Pr}) \quad (1)$$

where F_b, invoicing by the energy produced in €; E_v, energy produced in hours valley kWh; P_{mv}, price valley of market in cent €/Kwh; Pr, premium by installation b.4; E_p, energy produced in rush hours kWh; P_{mp}, price end of market in pts/Kwh.

The complement of energy renewal for electrical tariffs is calculated following the specifications of the Order of 12th January, 1995 in Section 7.2.[4]

$$\cos\varphi = \frac{E_a}{\sqrt{E_a + E_r}} \quad (2)$$

where cos ϕ, power factor; E_a, active energy kWh; E_r, energy reactivates kWh.

The closer is the cos $\phi$to the unit, the more will be the value of discount reaching a maximum established in 4%.

3.4. Consumption of energy

The consumption of primary energy in Spain, according to statistics in the data reflected in the document of Power Efficiency and Renewable Energies, shows an increase of 2.1%

[4] According to art. 7.2.1 Order of 12 January 1995, “the complement by energy reactivates this constituted by a surcharge or discount percentage and was applied to the basic invoicing. Decimal calculated with a number and clear will become pro defect or by excess, according to which the despised number decimal is or non smaller of five”.

in 2001 with respect to the consumption of the previous year. This fact comes by the economic deceleration from the previous year due to the reduction power demand, established at 4.8%.

As is reflected in the Document of Power Efficiency and Renewable Energies [11] “the consumptions of renewable energies increased to their participation in the power demand total Spanish of 2001 until 6.5%, fundamentally as a result of the increase of the hydroelectric production, that happens to represent 2% of the total of the consumptions to 2.8% including all the greater and smaller power plants of 10 MW and welcomes, as much to the Ordinary Regime and Special Regime of electricity production.”

4. Present situation in Spain

Spain, at the end of year 1998, had a total of installed power of 1510 MW, which represents more than 15% of the 9800 MW approximately developed in the European level as seen in Fig. 2, Spain occupies the third place in terms of installed hydroelectric power of less than 10 MW after Italy and France.

For the case of power stations with more than 10 MW, the installed power arrived at a total of 11,523 MW, which represents more than 13% of the 83,673 MW developed at the European level.

The evolution of the hydroelectric power (seen in Fig. 3) in Spain has been very fast, from 1986 to 2001. The total accumulated power is 1607.3 MW, showing an average annual growth of 53 MW every year. 1992 and 1993 show an increase of more than 50% because the investment made were 117.46 and 86.34 M€, respectively.

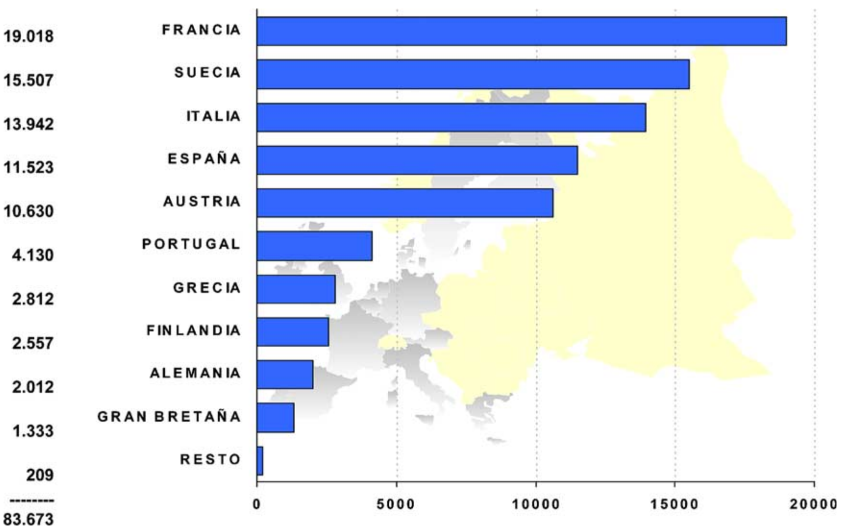
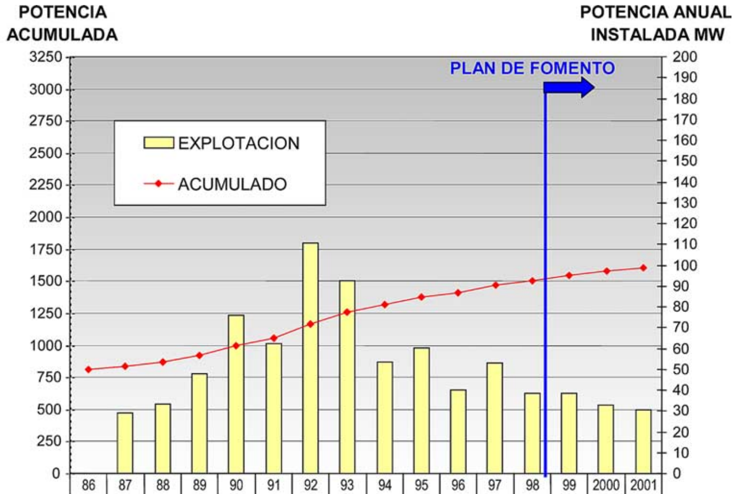


Fig. 2. Graphical Hydroelectric 2: power installed CH > 10 MW in UE 31/12/98. *Source*: own elaboration from PLAFER data (1999).



	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000	2001
EXPLOTACION		29,2	33,4	47,8	75,6	62,3	110,7	92,5	53,7	60,4	40	52,8	38,6	38,6	32,7	30,9
ACUMULADO	808,1	837,3	870,7	918,5	994,1	1056	1167	1260	1313	1374	1414	1467	1505	1544	1576	1607

Fig. 3. Evolution of Hydroelectric Power (MW) in Spain. *Source*: own elaboration from PLAFER data (1999).

The Independent Communities with greater presence of hydroelectric energy are Castile and Leon, Catalonia, Andalusia, Aragón, Navarre and Galicia (Fig. 4). Each one of the independent communities has a renewable source, although most remarkable are the communities of Andalusia and Castile and Leon. In the last one, a bullish tendency towards development of the hydroelectric power exists, because more than 15% of the total installed hydroelectric power is located in this community. A similar development is seen in Catalonia with a total of 14% of the total installed hydroelectric power. The general impact in the rest of the Communities is to the reduction of the facilities.

		PLAN DE FOMENTO			
	HASTA 1998	1999	2000	2001	TOTAL
CASTILLA Y LEÓN	225,4	5,6	3,5	14,9	249,4
CATALUÑA	211,0	3,9	1,9	11,1	227,9
ANDALUCIA	186,7	0,9	2,1	--	189,7
ARAGÓN	173,6	14,6	2,1	0,1	190,4
NAVARRA	140,8	5,3	5,4	0,9	152,4
GALICIA	136,0	--	6,9	2,0	144,9
CASTILLA-LA MANCHA	94,7	--	0,2	0,2	95,1
ASTURIAS	80,8	--	4,3	0,4	85,5
CANTABRIA	51,5	--	--	--	51,5
PAIS VASCO	46,1	1,5	--	1,2	48,8
MADRID	45,3	--	--	--	45,3
LA RIOJA	42,6	--	--	--	42,6
VALENCIA	39,6	--	5,1	--	44,7
EXTREMADURA	19,6	--	--	--	19,6
MURCIA	17,0	--	1,2	--	18,2
CANARIAS	1,4	--	--	--	1,4
ESPAÑA	1512,0	31,8	32,7	30,8	1607,3

Fuente: IDAE

Fig. 4. Evolution until 2001 of hydroelectric power (MW) installed in the independent communities for hydroelectric power stations <10 MW. *Source*: own elaboration from data of the IDAE (2003).

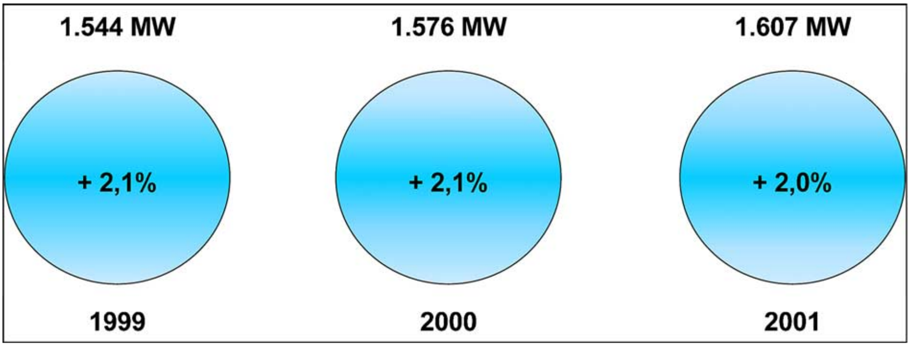


Fig. 5. Percentage increase of Hydroelectric Power (MW) installed in hydroelectric power stations <10 MW. *Source*: own elaboration from data of the IDAE (2003).

As can be observed in Fig. 5 which shows analysis of the percentage increase of the total installed power, growth of hydroelectric power stations with less than 10 MW, has been coming down to 2% for last 3 years, 1999–2001.

In a less exhaustive form, the growth for the case of hydroelectric power stations with power between 10 and 50 MW is analyzed, since not more than 0.7% growth had taken place in 2001.

This reduction of growth is not only because of the investment required for a hydroelectric power station, but also of certain reasons at administrative level slowness in transaction of concessional files and in authorization of organisations such as (communities), hurdles in granting of work licenses. Social and the environmental reasons such as negative perception by ecological groups, and lack of objective criteria from the environmental point of view [12] also contribute to the decrease. And for financiers, difficulty in financing projects by the uncertainty in tariffs and their duration.

In the Plan of Promotion of the Renewable Energies, the results of the only evaluation of the hydroelectric potential [13] stations of small power distributed along hydrographic river basins in Spain were made in 1980. Here the hydraulic potential gross is evaluated to be 150.360 GW h/year, from which the technically usable potential is obtained at 65,000 GW h/year. Of this, it is assumed that the hydroelectric potential for mine power stations developed at the moment is 31,600 GW h/year.

According to the Plan of Promotion of the Renewable Energies "To obtain these numbers is difficult in the short and mid term since many of the hydraulic advantages are located in sections of rivers reserved for fishing or including in natural parks, nevertheless are possible to be established the following values according to the Hydrographic River basins" (Fig. 6).

The hydroelectric objective that is mentioned in the White Book, which was approved on 26th November 1997 by the European Commission, was to reach 105,000 MW in 2010 in the European Union and to be distributed in the following way:

- Big power stations (>10 MW): 91,000 MW (including pumping power stations)
- Small power stations (<10 MW): 14,000 MW

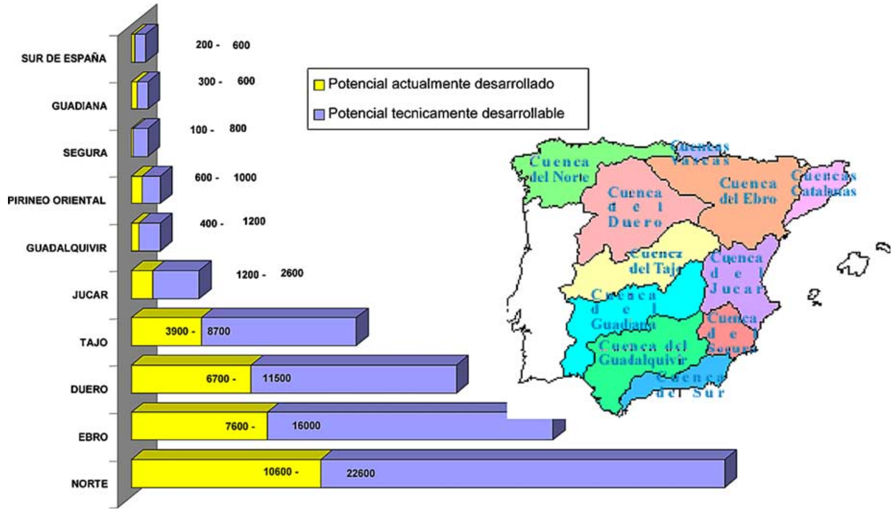


Fig. 6. Hydroelectric potential in Spain (GW h/year) by hydrographic river basins. *Source*: own elaboration from data INTECSA (1980).

This means that there must be an increase of 10% and almost 47% in big great and small power stations, respectively, as well as to produce 12% renewable of energy of the total electricity generated.

The forecasts made by the IDAE for the year 2010 are based on the following considerations: according to the Plan of Promotion, in the case of the hydroelectric power stations of ≤10 MW, the power necessary to obtain technically usable hydroelectric potential is 2230 MW, while annual capacity is 100 MW/year. The objective for year 2010 is to obtain an increase of 720 MW.

In Independent Communities, as seen in Fig. 7, those that have the most ambitious objectives of installing new power plants for 2010 according to the collected data of the IDAE are the communities of Castile Leon (229 MW) and Aragón (69 MW). In addition they are also the communities where more new mini-hydraulic power plants have been located.

In 2001, the total installed power of hydroelectric stations was 52.2 MW—two power stations, one of 30.8 MW capacity and the other of 20.4 MW. This is different for the case of power stations with equal or inferior power to 10 MW. This is of a power between 10 and 50 MW has been installed in mini-hydraulics, a power station of 20.4 MW has settled. (Fig. 8).

With 30.8 MW (Fig. 9) of power installed in mini hydraulics, PLAFER is fulfilled to a certain extent, in 2001, 50% of the power installed with respect to that established in 2010, according to the Plan of Promotion. The average evolution of the installed power is 31.8 MW annually, although continuous fluctuations around this average are observed.

Among the measures that will boost future development is, in the first place, the maintenance of an effective tariff system. In this sense, at the end of 2002, revision of the established premiums was made. As per article 32 of the Real Decree 2818/98, the evolution of price of the electrical energy in the market, the participation of facilities of the special regime in the cover of the demand and its incidence on the technical management

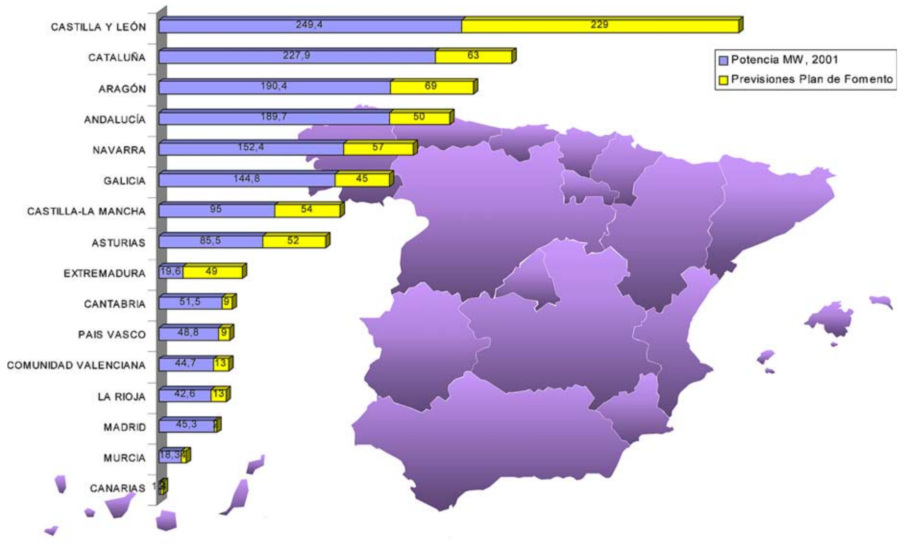


Fig. 7. Distribution by CCAA of the hydraulic advantages (<10 MW). *Source*: own elaboration from data of the IDAE (2003).

of the system are to be taken care of. The variation is of 1.69% on the tariffs that took effect on January 1, 2002 according to the existing RD 1482/2001.

At the moment in Spain, with the present power structure and extension of the distribution network, the systems in the islands do not have, nor is foreseeable that they have, a significant level of power contribution within the national scope. The only

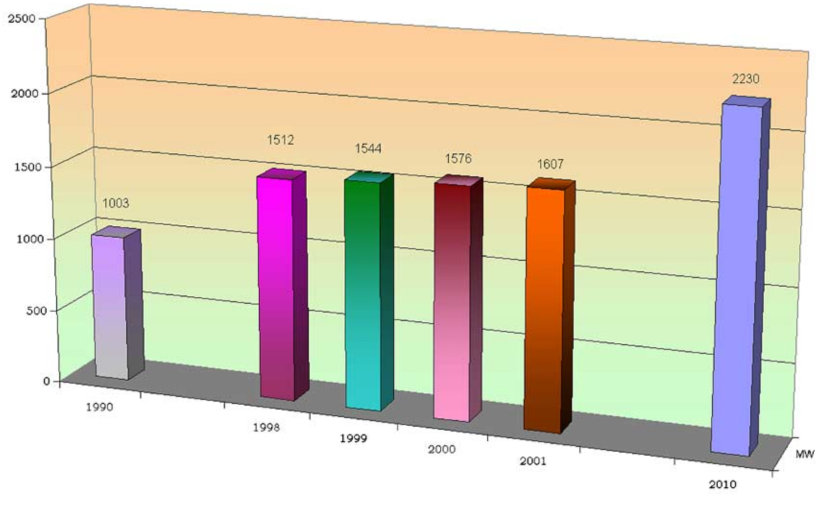


Fig. 8. Installed mini hydraulic power and forecasts (MW), power stations <10 MW. *Source*: own elaboration from data of PLAFER, December 1999.

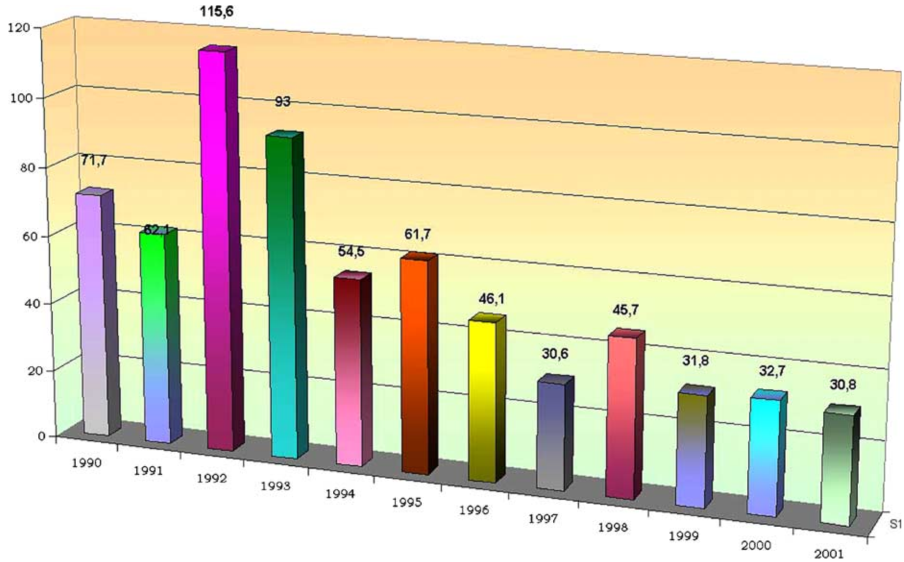


Fig. 9. Installed power of mini hydraulic <10 MW in Spain (MW). *Source*: own elaboration from PLAFER data: 1999.

foreseeable quantitative evolution of the sector is in the mini power stations connected to the distribution network. Even so, a sustained growth of the installed power shows what the future is likely to be.

In spite of being a clean and native energy, it generates a power in part guaranteed and, in general, with regulation of frequency and tension, an increase of sustainable power that continues due to improvements in the present mini-power stations. The improvements include commencing administrative work, the construction of mini-power stations in new locations, and in the purchase that is anticipated at the moment or rent of mini-power stations already in operation.

As far as the renovation perspective technology is concerned, it is seen that no short or half-term remarkable evolution has not yet developed. In the last few years, main innovations have taken place in the field of the control and the automatization with the consequent improvement of yields.

The maintenance of the present growth has consolidated in Spain, when compared to the hydraulic sector at a worldwide level. The forecasts for the next few years allow prediction of the maintenance of this condition, as well as the fulfillment of the pre-selected targets in the Plan of Promotion.

However, the permanence of the reviewed obstacles, in relation to the administrative problems, delays in granting of licenses and concessions, and environmental advice to maintain certain caution on the future evolution of the sector need to be reviewed.

The explicit recognition of the renewable energies in the Law of the Electrical Sector has been a determining factor in the development of hydroelectric energy. The maintenance of this support needs factors fundamental in guaranteeing the attainment of the anticipated hydraulic objectives.

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